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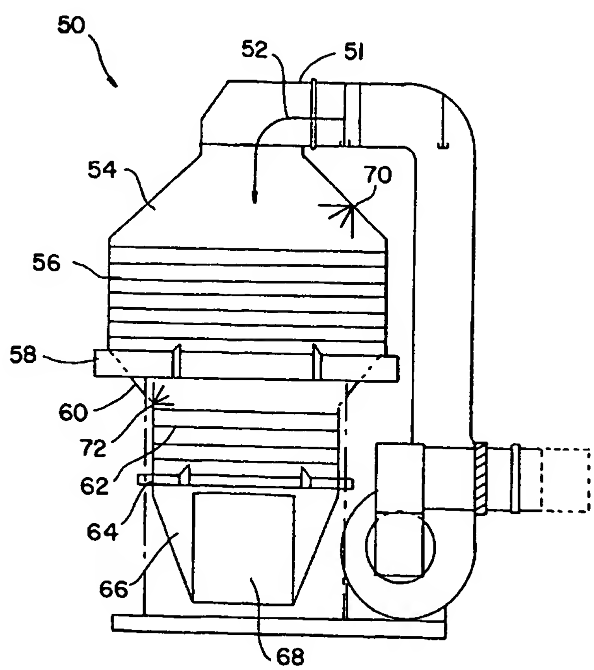
(54) Flue gas treatment

(57) A two-stage downflow flue gas treatment condensing heat exchanger system (50) allows for flue gas to be passed into a two-stage housing at an upper end of the housing. The flue gas is channelled through a first stage of the housing having a first condensing heat exchanger (56) which cools the flue gas. The flue gas is then channelled through a second stage having a second condensing heat exchanger (62) which is located directly beneath the first stage and the first condensing heat exchanger (62) for further cooling the flue gas. The flue gas travels in a downward direction only through the housing and exits the housing at the lower end of the housing beneath the second stage. A collection tank (66) is located beneath the second stage of the housing for collecting liquids, condensate, particulates and reaction products.

FIG.3



CORRIGENDUM Issued on 14.02.96

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Description

The present invention relates, in general, to the removal of contaminants from flue gas, and in particular to systems and methods for treating flue gas.

In the power generating field, there are several known devices and methods which relate to the integrated heat recovery and pollutant removal of particulates, sulphur oxides and/or contaminants from a hot combustion exhaust gas for complying with US federal and state emissions requirements.

One device which has been used is a condensing heat exchanger, as shown in Figure 1 of the accompanying drawings, which recovers both sensible and latent heat from flue gas 11 in a single unit 10. The device allows for the gas 11 to pass down through a heat exchanger 12 while water 14 passes upwards in a serpentine path through the tubes of the heat exchanger 12. Condensation occurs within the heat exchanger 12 as the gas temperature at the tube surface is brought below the dew point. The condensate falls as a constant rain over the tube array of the heat exchanger 12 and is removed at the bottom by a condensate drain 16. Gas cleaning may occur within the heat exchanger 12 as the particulates impact the tubes and gas condensation occurs.

The heat exchanger tubes and inside surfaces of the heat exchanger shell are made of corrosion resistant material or are covered with Teflon (registered trade mark) in order to protect them from corrosion when the flue gas temperature is brought below the acid dew point. Interconnections between the heat exchanger tubes are made outside of the tube sheet and are not exposed to the corrosive flue gas stream 11.

Another device which has been proposed is an integrated flue gas treatment (IFGT) condensing heat exchanger 20, schematically shown in Figure 2 of the accompanying drawings, which is a condensing heat exchanger designed to enhance the removal of pollutants from a flue gas stream 22. This device is also made of corrosion resistant material or has all of the inside surfaces covered by Teflon.

There are four major sections of the IFGT 20; a first heat exchanger stage 24, an interstage transition region 26, a second heat exchanger stage 28, and a mist eliminator 30. The major differences between the integrated flue gas treatment design of Figure 2 and the known condensing heat exchanger design of Figure 1 are:

1. the integrated flue gas treatment design uses two heat exchanger stages 24 and 28 instead of one heat exchanger 12 (Figure 1);

2. the interstage or transition region 26, located between the heat exchanger stages 24 and 28, is used to direct the gas 22 to the second heat exchanger stage 28, and acts as a collection tank and allows for treatment of the gas 22 between the stages 24 and 28;

3. the gas flow in the second heat exchanger stage 28 is upward, rather than downward;

4. a gas outlet 29 of the second heat exchanger stage is equipped with an alkali reagent spray system 40 comprising a reagent source 42 with a pump 44 for pumping reagent, recirculated condensate, and spent reagent to sprayers 46 and 48; and

5. the mist eliminator 30 is used to separate the water formed by condensation and sprays from the flue gas.

Most of the sensible heat is removed from the gas 22 in the first heat exchanger stage 24 of the IFGT 20. The transition region 26 can be equipped with a water or alkali spray system 48. The system 20 saturates the flue gas 22 with moisture before it enters the second heat exchanger stage 28 and also assists in removing sulphur pollutants from the gas 22.

The transition piece 26 is made of or lined with corrosion resistant fiberglass-reinforced plastics or other corrosion resistant material. Additionally, the second heat exchanger stage 28 is operated in the condensing mode, removing latent heat from the gas 22 along with pollutants. Also, the top of the second heat exchanger stage 28 is equipped with an alkali solution or slurry spray device 46. The gas 22 in this stage 28 is flowing upwards while the droplets in the gas 22 fall downwards. This counter-current gas/droplet flow provides a scrubbing mechanism that enhances particulate and pollutant capture. The condensed gases, particulates, and reacted alkali solution are collected at the bottom of the transition section 26. The flue gas outlet 29 of the IFGT 20 is equipped with the mist eliminator 30 to reduce the chance of moisture carryover.

According to one aspect of the invention there is provided a system for treating a flue gas, the system comprising:

a housing having an inlet at an upper end and an outlet at a lower end, the flue gas entering the inlet and travelling downwardly through the housing and exiting through the outlet;

first heat exchanger means near the upper end of the housing for cooling the flue gas;

second heat exchanger means in the housing beneath the first heat exchanger means for further cooling the flue gas; and

collection means at the lower end of the housing below the second heat exchanger means for collecting liquids and particulate.

According to another aspect of the invention there is provided a method of treating a flue gas, the method comprising:

passing a flue gas into a two-stage housing at an upper end of the housing;

channelling the flue gas through first heat exchanger means at a first stage of the housing for cooling the

flue gas;

channelling the flue gas through second heat exchanger means at a second stage of the housing beneath the first heat exchanger means for further cooling the flue gas;

collecting liquids and particulate beneath the second stage of the housing; and

exiting the flue gas from the housing at a lower end of the housing beneath the second stage.

Thus, in a preferred embodiment of the invention, flue gas enters the housing at the inlet and travels downwardly through the housing and exits the housing at its lower end through the outlet. The housing has an upper stage beneath the inlet which contains the first condensing heat exchanger which withdraws heat from the flue gas in order to cool the flue gas as the flue gas is channelled downwardly through the housing. A second stage located directly beneath the first stage contains the second condensing heat exchanger which provides a further cooling of the flue gas by withdrawing more heat from the flue gas as the flue gas passes downwardly through the second stage towards the outlet. The collection tank is located at the lower end of the housing beneath the second heat exchanger, and collects condensate, liquid, particulates and reaction products.

Preferably, a mist eliminator is located at the lower end of the housing beneath the collection tank for demisting the flue gas prior to its exit through the outlet. A reagent spray system may be located at the second stage for spraying the flue gas with an alkaline reagent solution or slurry for removing contaminants such as sulphur dioxide (SO_2) from the flue gas. A spray wash system may also be located at the upper end of the housing for spraying cleaning liquid down the housing for cleaning both heat exchanger stages.

Accordingly, the preferred embodiment of the present invention provides a system and method for treating a flue gas which utilizes two separate stages in a vertical relationship for channelling the flue gas in a downward direction only. Useful heat can be recovered while removing particulates (fly ash), sulphur oxides and/or other contaminants contained in flue gases formed during the combustion of waste materials, coal and other fossil fuels, which are burned by electric power generating plants, waste-to-energy plants and other industrial processes through the use of the two-stage downflow flue gas treatment condensing heat exchanger.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

Figure 1 is a schematic view illustrating a known condensing heat exchanger system;

Figure 2 is a schematic view illustrating an integrated flue gas treatment system; and

Figure 3 is a schematic view illustrating a two-stage downflow flue gas treatment system according to an embodiment of the present invention.

A two-stage downflow flue gas treatment condensing heat exchanger system and method using co-current gas/droplet flow and embodying the invention will now be described with reference to Figure 3. The purpose is to provide improved heat recovery and pollutant removal performance compared to the IFGT system shown in Figure 2.

Referring to Figure 3, a two-stage device 50 has two condensing heat exchanger stages 56 and 62, mounted vertically in series, in which flue gas 52 enters at the top of the device 50 through an inlet 51 and exits at the bottom of the device 50 through an outlet 68. A transition section 60 separates the two heat exchanger sections 56 and 62. The transition section 54 communicates between the inlet 51 and the first heat exchanger 56. Structure 58 is used to support the first heat exchanger 56. Structure 64 supports the second heat exchanger 62.

Most of the sensible heat is removed from the flue gas 52 in the first heat exchanger stage 56 and, after being passed through the transition section 60, the flue gas 52 enters the second or lower heat exchanger stage 62 where latent heat is removed. Droplets are formed in both stages due to condensation. The droplets fall downwards due to the combined effects of gravity and the downward travel direction of the flue gas flow 52. The second heat exchanger stage 62 can be smaller than the first stage 56 in order to maintain the optimum velocity around the tubes for the cooler gas.

A collection tank 66 is provided near the bottom of the second stage 62 to collect the water droplets, condensed gases, particulates, reaction products, and alkali reagent. Additional collection mechanisms can also be added in the region of the collection tank 66 to aid in the removal of particulates and pollutants from the flue gas stream 52.

The top of the second stage 62 is optionally equipped with an alkali reagent spray system 72 to provide enhanced removal of sulphur oxides and other pollutants from the gas 52. The gas 52 leaves the second heat exchanger stage 62 and passes through a mist eliminator which is not shown but is located in the region of outlet plenum 68. The liquid collected by the mist eliminator is fed back to the collection tank 66 through recycle or channelling means.

The two-stage downflow flue gas treatment device 50 also includes a spray washing system 70 located at the top of the device 50. Periodic washing of the heat exchanger tubes of the heat exchangers 56 and 62 prevents potential plugging of the heat exchangers 56 and 62 and provides consistent thermal performance.

The major differences between the two-stage downflow flue gas treatment system 50 and the IFGT system 20 (Figure 2) are:

1. The flue gas flows in the downward direction in the two-stage downflow flue gas treatment system 50 unlike the multi-directional flow of the IFGT system 20. In the IFGT system 20, the direction of gas flow in the second heat exchanger 28 is upward.

2. In the IFGT system 20, the direction of flow for the particulates and droplets collected in the second stage 28 is opposite to the direction of the flue gas flow. For the two-stage downflow system 50, the direction of flow in the heat exchangers is always the same for the flue gas, droplets, and particles, i.e. downward.

3. In the IFGT system 20, the particulates and droplets in the second stage 28 must be large enough to overcome the drag forces of the flue gas 22 before they reach the collection area 26. This is not a requirement for the two-stage downflow design embodying the present invention.

4. In the IFGT system 20, the transition section 26 acts as the collection means. The transition section 26 is located between the first and second heat exchanger stages 24 and 28, upstream from the coolest regions of the heat exchanger. The direction of flue gas flow in the second stage 28 is away from the collection region 26. For the two-stage downflow system 50 embodying the present invention, the collection tank 66 is downstream from the second heat exchanger stage 62. It is located downstream from the coolest regions of the heat exchanger 62 and the direction of the flue gas flow is towards the collection tank 66.

The two-stage downflow flue gas treatment system 50 is an improvement over the IFGT design 20. The advantages listed below compare the performance of the two-stage downflow flue gas treatment system 50 with a IFGT design 20.

The present system has a smaller footprint than the standard IFGT condensing heat exchanger design, thus requiring less space for installation.

The present system has a lower gas side pressure drop than comparable IFGT designs. The reason for this is that all of the flow is in the downward direction. The downflow (co-current droplet/gas flow) in the second heat exchanger stage 62 has a lower pressure drop than the gas upflow, droplet/particulate downflow condition (counter-current droplet/gas flow) encountered in the IFGT design. The lower pressure drop will permit a smaller forced or induced draft fan to be used in retrofit applications and result in lower parasitic losses during operation.

The present system has superior heat recovery performance when compared to IFGT designs. Testing performed on the condensing heat exchangers 56 and 62 has demonstrated that the gas downflow design provides maximum heat recovery performance. All of the heat recovered in the present system is recovered under gas downflow conditions, while the second stage 28 of the IFGT design 20 recovers heat under gas upflow conditions.

The present system also has improved particle removal performance, especially for very small particulates. The upflow direction of the flue gas stream 22 in the second stage 28 of a standard IFGT 20 carries particles away from the collection means 26. In the standard IFGT design 20, very small particles will not be removed unless they become large enough (through water condensation, etc.) to overcome the drag forces of the gas stream and can fall back through the heat exchanger 28 to the collection means 26. In the present system, however, the downflow direction of the flow stream 52 always directs the particulates towards the collection tank 66.

The present system has improved condensable gas removal performance. Condensable gases, such as heavy metals and organic compounds, will form in very small droplets in the cooler regions of the heat exchanger. For the IFGT design 20, the coolest region of the heat exchanger 28 is downstream of the collection means 26. For the same reasons as explained above, many of the condensable gas droplets formed in the IFGT design 20 will be carried out with the gas stream 22 and can only be collected in the mist eliminator 30. In the present system, however, the downflow direction of the flow stream 52 always directs the droplets towards the collection tank 66. In this case, the mist eliminator in the region of the outer plenum 68 captures those droplets that are not removed at the collection tank 66.

The single water spray system 70 in the present system cleans the whole area of both heat exchangers 56 and 62 since the cleaning water will flow through both heat exchangers. In the IFGT design 26, two separate spray cleaning systems are required to achieve the same result.

The loading on the mist eliminator is less for the present system because most of the mist will be removed in the collection tank 66. The small mist droplets will have a greater opportunity to form into larger droplets in the two-stage downflow design 50, and the momentum forces imparted to the droplets by the flue gas 52 are in the direction of the collection tank 66. For the IFGT design 20, most of the mist leaving the heat exchanger 28 will reach the mist eliminator 30, and when collected, must form droplets of sufficient size to be removed from the gas stream 22 and drained to the collection means 26.

Although not shown, the present system may incorporate other features which have not been described above. The present system may also include a third heat exchanger stage which could be added downstream of the second stage to improve the removal of condensing organics, heavy metals, and other condensible air pollutants from the flue gas. The third stage would operate independently of the rest of the system and would not be used for heat recovery. The third stage would have a

closed cycle refrigerant loop, similar to a dehumidifier, for the purpose of lowering the flue gas temperature further to remove the condensible pollutants.

Also, the present system can be tailored to incorporate multiple stages, rather than just the two stages described above. Each stage would be designed to optimize the removal of a particular pollutant of concern and would pretreat the flue gas for the next stage.

An additional transition section can also be added between the outlet of the second stage and the mist eliminators to coalesce droplets and particulates and/or impart momentum to the droplets and particulates in order to increase separation performance before the exhaust gas enters the mist eliminators.

The present system can be used to pre-treat a flue gas prior to entering a wet scrubber. Advantages of this use include: lowering the inlet flue gas temperature which will allow the wet scrubber to operate more efficiently for sulphur oxides removal; the two stage downflow unit can be used to subcool the flue gas to maximize removal of particulates, HF, HCl, and condensable air toxics while the wet scrubber would produce high quality gypsum without the need for additional washing if the two-stage downflow unit removed undesirable materials, such as chloride ions and inert particulates, during pretreatment of the flue gas; and there would be less reagent lost in a sodium regenerable process if the two-stage downflow unit removed HF, SO_3, NO_2, and HCl during pre-treatment of the flue gas. This application would also reduce or eliminate the need for a purge to remove inert materials from the process.

Claims

1. A system for treating a flue gas, the system comprising:

   a housing having an inlet (51) at an upper end and an outlet (68) at a lower end, the flue gas entering the inlet (51) and travelling downwardly through the housing and exiting through the outlet (68);

   first heat exchanger means (56) near the upper end of the housing for cooling the flue gas;

   second heat exchanger means (62) in the housing beneath the first heat exchanger means (56) for further cooling the flue gas; and

   collection means (66) at the lower end of the housing below the second heat exchanger means (62) for collecting liquids and particulate.

2. A system according to claim 1, including reagent spray means (72) for cleaning pollutants from the flue gas.

3. A system according to claim 1 or claim 2, including washing means (70) for washing the first and second heat exchanger means (56,62).

4. A system according to claim 1, claim 2 or claim 3, including mist elimination means (68) for removing mist from the flue gas.

5. A system according to claim 4, wherein the mist elimination means (68) is located near the outlet (68).

6. A system according to claim 4 or claim 5, including recycle means for recycling liquid from the mist elimination means (68) to the collection means (66).

7. A system according to any one of the preceding claims, wherein the first heat exchanger means (56) is larger than the second heat exchanger means (62).

8. A system according to any one of the preceding claims, including a transition section (60) between the first heat exchanger means (56) and the second heat exchanger means (62).

9. A method of treating a flue gas, the method comprising:

   passing a flue gas into a two-stage housing at an upper end of the housing;

   channelling the flue gas through first heat exchanger means (56) at a first stage of the housing for cooling the flue gas;

   channelling the flue gas through second heat exchanger means (62) at a second stage of the housing beneath the first heat exchanger means (56) for further cooling the flue gas;

   collecting liquids and particulate beneath the second stage of the housing; and

   exiting the flue gas from the housing at a lower end of the housing beneath the second stage.

10. A method according to claim 9, including removing mist from the flue gas.

11. A method according to claim 9 or claim 10, including washing the first and second heat exchanger means (56,62).

12. A method according to claim 9, claim 10 or claim 11, including cleaning the flue gas with a reagent.

FIG.1
(PRIOR ART)

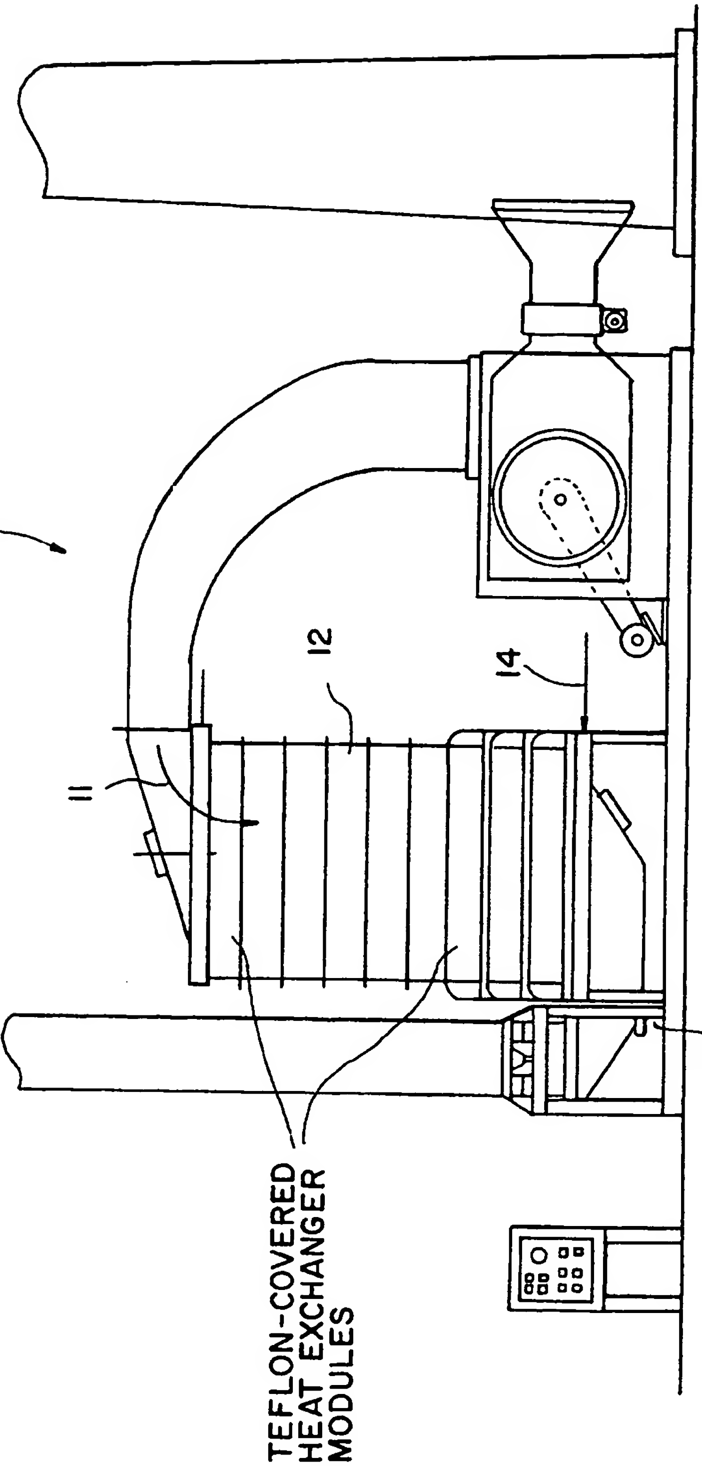

FIG. 2

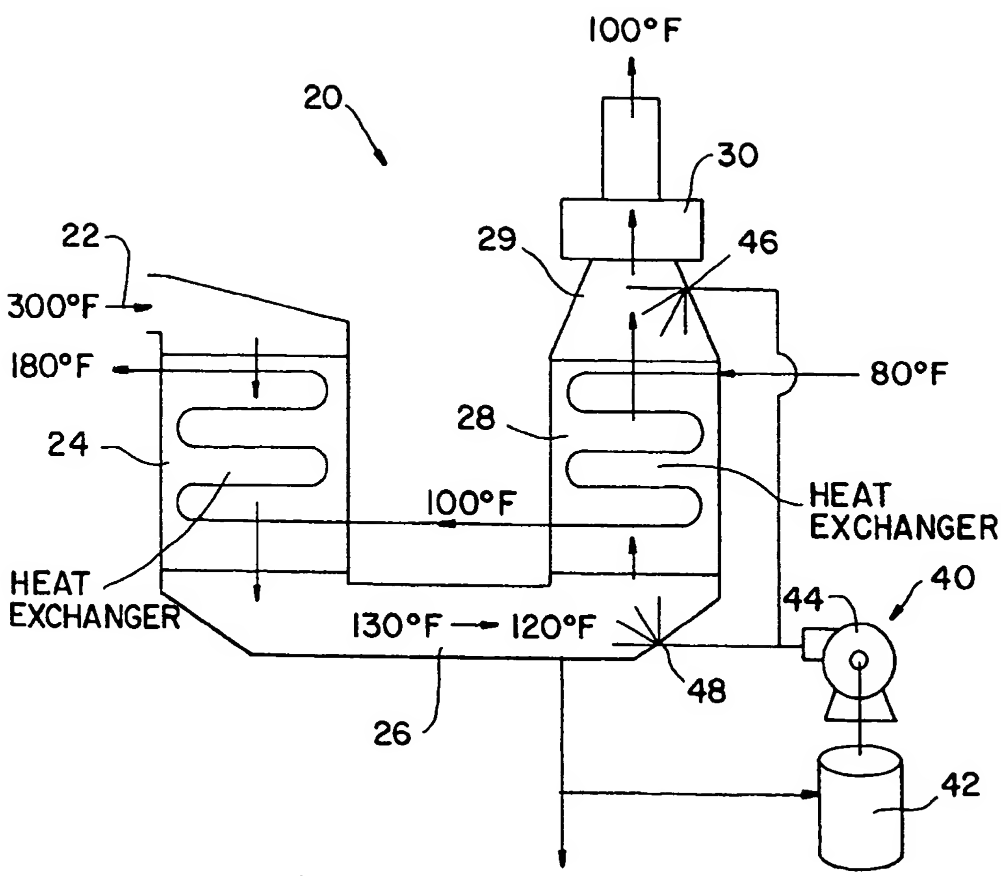
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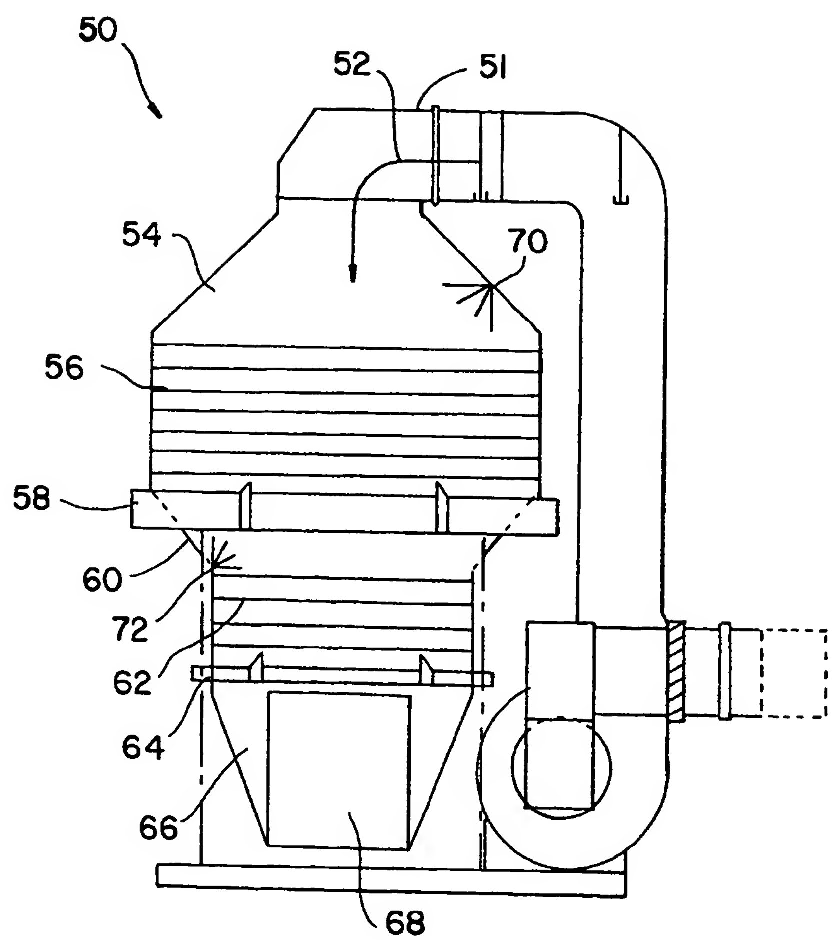
FIG.3



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EUROPEAN SEARCH REPORT

Application Number
EP 95 30 4649

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	FR-A-2 586 204 (P.TISSANDIER) * claims; figure 1 *	1-12	B01D53/00 B01D53/50 F23J15/00 F23J15/06 F28D21/00
A	FR-A-2 592 812 (SOBEA) * claims; figures 2,3 *	1,9	
A	DE-A-37 06 864 (B.NIBBRIG) * claims; figure 1 *	1,9	
A	EP-A-0 583 197 (AQUAFRANCE) * claims; figure 1 *	9	
A	EP-A-0 432 074 (SOGEA) * claims; figure 1 *	9	
A	FR-A-2 224 193 (UNIVERSAL OIL PRODUCTS COMPANY) * claims; figure 2 *	1,9	
A	PATENT ABSTRACTS OF JAPAN vol. 12, no. 67 (M-673) (2914) 2 March 1988 & JP-A-62 213 610 (YOUEI SEISAKUSHO KK) 19 September 1987 * abstract *	1,9	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B01D F23J F28D F28G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	31 August 1995	Cordero Alvarez, M

CATEGORY OF CITED DOCUMENTS

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